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ABSTRACT

This guide explains how to establish a research program within a school and how to get students involved in independent research projects and national research competitions. Chapter 1, "Selling the Program," examines benefits to the community, school, teachers, and students. Chapter 2, "Assessing Your Situation," discusses how independent research fits with current educational practices and how to survey community resources. Chapter 3, "Practical Considerations for the School," looks at program models, creating a budget, and finding facilities. Chapter 4, "Practical Considerations for the Teachers," discusses recruiting and selecting students, a case study in selecting students, teaching techniques, grading policy, identifying projects, and identifying and defining mentors. Chapter 5, "The Curriculum," focuses on defining independent research projects for students, using the scientific method, keeping a research notebook, using statistical methods, presenting papers, presentation aids, answering questions, ethical and moral considerations, and safety concerns. Chapter 6, "The Next Steps," discusses the steps needed to maintain the program and let it grow. Throughout the book, examples are provided of a research program at one New York high school. Three appendixes describe the competitions, sample project titles, and opportunities for students. (SM)

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How to

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CONDUCTING INDEPENDENT RESEARCH PROGRAM

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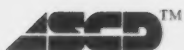
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How *to* **CREATE AN INDEPENDENT RESEARCH PROGRAM**

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Introduction

In 1986, I was asked to create an Independent Research Program at Ward Melville High School in Setauket, New York. The program's goal was to encourage students to work on independent research projects in the sciences and mathematics and then to have them enter research papers about the projects in the national competitions. Among the competitions we targeted were the Intel/Westinghouse Science Talent Search, the International Science and Engineering Fair, and the Junior Science Humanities Symposium.

As an introduction, I decided to take my class to the regional competition for the Junior Science and Humanities Symposium at a local university. I felt that this would be an excellent way to motivate my students and to show them the scope and sequence of independent research projects.

We arrived, found our room, and prepared to listen to our first presentation. In the front of the room, a high school student was presenting his biology research project. He was using two projectors—one with slides, the other with view graphs. His presentation was smooth and practiced and he used an extensive biology vocabulary. We were overwhelmed by what we saw. After lunch, we listened to two more sophisticated presentations. We returned to Ward Melville High School feeling discouraged, wondering how we could do something that accomplished.

The next day, we talked about our experience. The students began to realize that the presenters were ordinary high school students just like them—only the student presenters had worked on a major independent

research project and had practiced their talk. My students decided to give research a try.

We began the Ward Melville High School Independent Research Program. (At the time, the program was named West Prep in recognition of the Westinghouse Corporation, sponsor of the Science Talent Search Program. Intel is now the sponsor of the Science Talent Search Competition.) The students began to work on their projects and subsequently entered the Junior Science and Humanities Symposium, as well as the other major research competitions. One year later, two students were selected to make their presentations at the regional Junior Science and Humanities Symposium. Three years after beginning our research program, a Ward Melville High School student placed second overall in the regional competition. By the seventh year, our high school was widely recognized as one of the dozen or so high schools in the nation that regularly win academic competitions.

The students at Ward Melville High School have become so committed to their work and their lab experiences that they give up their summer vacations to work on projects. Although most of the students have entered their projects in the Science Talent Search Competition, many were not semifinalists. The students, however, have enjoyed their projects and their research experiences. The feedback I receive every year is that the students have learned a great deal about "real" science. Some students received partial college scholarships and paid internships as a result of their independent research experiences; unlike many college students who work to earn extra money, research students get paid to do the very thing they love to do best. The research students believe that "to be in it is to win," the motto of our research program.

Hundreds of students have been part of the Independent Research Program at Ward Melville High School. By all of the accepted criteria for measuring success, the independent research classes have been outstandingly successful. Students have been named regional, state, and national winners in every major science and math competition. In 1997 and 1998, Ward Melville High School produced more Science Talent Search Finalists than any other public school in the United States (only 40 Finalists are announced nationwide). In 1997, three Finalists were from Ward Melville and in 1998, four Finalists were from Ward Melville. Also in that timeframe, Ward Melville High School was honored by two

students being named national second place winners in the Duracell Scholarship Competition, two students receiving an International Gems Award from the ThinkQuest Competition, the school's team being named state champion in the Science Olympiad Competition, and having a student who was a national finalist in the National Space Science Involvement Competition. In addition, dozens of students have placed 1st, 2nd, or 3rd at local science, social science, and math competitions.

Ward Melville High School is a public suburban school on Long Island, about 50 miles east of New York City. The school resembles hundreds of other suburban high schools across the nation. Nothing about the school district or its students would predict its remarkable research accomplishments, although 72 percent of the graduates are accepted into four-year colleges. What the school does have is a program dedicated to independent research projects. The program has created a culture that encourages and supports students who are willing to make a commitment to work on independent research projects.

What exactly are independent research projects? They are quite different from the projects usually found at school science fairs and are distinct from social science presentations. Independent research projects are not simple models of the ear or solar system, rock and fossil collections, or reports on the electoral system. Instead, independent research projects are actual laboratory research projects created by a student or a team of students. Students may work in any area of their choice; often the projects fall in the areas of behavioral and social sciences, mathematics, biological sciences, and physical sciences. Many projects in English and social studies classes can also be independent research projects. In the past five years, I have had students involved with projects in the social sciences, economics, linguistics, mathematics, the physical sciences, and the biological sciences. A sample of project titles in the various fields can be found in Appendix II.

Independent projects are open-ended. The problems that students pose have no set answers. Teachers help students to understand that their original plans or hypotheses may not be successful and that they may encounter many failures before they are successful. Throughout the independent research program, students need to understand that failure in research is not equal to failure on a test, or failure in a laboratory experiment, but rather is a road sign to other researchers to try a differ-

ent approach. Post-It Notes would not be on the market today if researchers had not failed while trying to create a new type of super glue.

Although the curriculum of the independent research course is based on the objectives of various national competitions, the course itself is not competitive and the students do not find themselves in a competitive environment. Instead, the competition rules are used to create a working atmosphere that resembles the professional world. Students are asked to comply with competition constraints and deadlines that are outside the conventional high school curriculum. At the same time, the role of the teacher is changed from lecturer to mentor and coach. One important tenet of the independent research course is that students must complete their projects; however, they do not have to enter the competition. Not having to enter a competition creates a classroom environment where, as stated before, "to be in it is to win."

Are these competitions only for the elite students? The answer is a resounding "No!" Are these projects only for the elite students? No!

All students are capable of working on independent research projects. In fact, I have found that the three most important criteria for predicting a student's success are perseverance, initiative, and motivation. Many students with high grade-point averages were in the West Prep program, but many students with average grade-point averages were also in the program and did very well.

This book will explain how to establish a research program in your school and how to get your students involved in independent research projects and national research competitions. Although several hundred schools across the country have research programs, thousands more do not have such programs. It is true that some of the schools with programs are magnet schools or highly advantaged schools, but many ordinary schools also have programs and are doing quite well. Every school is capable of at least a modest program for those students who want to work on independent research projects. Use this book as your step-by-step guide to creating an independent research program and preparing your students to enter the national independent research competitions. I hope you will agree that to be in it is to win.

—MELANIE JACOBS KRIEGER

1 Selling the Program

Is an independent research program something that you want in your school? If it's not part of the curriculum or a logical extension of the current curriculum, you may have to start by selling your idea to the administration, the board of education, and perhaps the community. How do you get your community and your school district officials interested in sponsoring a research program? At the very least, how do you receive permission to integrate independent research projects into your current curriculum? You'll have to sell the school district officials and community on the benefits of the independent research experience. Convince them that involving students in independent research projects provides benefits for the community, the school, the student, and the teacher. In every state there are a few high schools that have an independent research program, though the vast majority of high schools don't have such programs. Visit one or two schools with developed independent research programs, or send for materials to build a portfolio of what is being done in other schools. If you don't know of any independent research programs to begin with, track the winners from the national or local competitions (see Appendix I) and ask those schools for information about their programs.

Part of selling the program includes assessing your local area to see what community colleges, businesses, industries, residents, and other resources can provide. For example, local colleges may allow students to take courses, faculty may serve as mentors to students and as judges and readers in school-based and countywide competitions. Local busi-

nesses often supply products for the students and the school. My students have received hardware building products to use for Duracell and Science Olympiad projects and one business donated T-shirts for the Science Olympiad team. Local industries may be persuaded to donate engineering time to help students with the projects.

Suggestions for involving community members includes car pools and drivers to take younger students to the library and to research labs—and to work with students on their projects. For example, community plumbers and welders helped students to build a vehicle for the Science Olympiad Competition.

Benefits to the Community

As the students become proficient in working on independent research projects, they will begin to enter various local, state, and national competitions and have their work published in professional journals. The students' accomplishments will be announced in newspapers and on radio and television, providing free publicity for the community and increasing awareness in the sort of projects completed in the schools.

The members of the community, local industries, and local colleges and universities will want to become involved with the students and their projects. In my community, residents with a background in research and companies with employees in research have been extremely helpful. Working together—educators and students collaborating with businesspeople and residents—improves the sense of community. And, the community itself may become a more desirable place to own a home as the academic reputation of the schools grows.

Benefits to the School

When students' accomplishments in national competitions and community projects are announced in newspapers and on radio and television programs, the school is filled with pride and the spirit of success. The students, teachers, and administrators involved in the program are proud and happy to say that these prize-winning projects started in their school and that they know and work with the students who developed them. At the same time, the other students and teachers will become

aware of the kinds of work being done in the independent research classes. And the publicity will make the school known to the community outside the local school district, thus increasing the district's prestige. Local media and corporations are usually eager to help with well-deserved publicity when students enter local, district, and national research competitions.

Benefits to Teachers

Because no two independent research projects are the same, independent research teachers find themselves working in a stimulating atmosphere constantly filled with new issues and challenges. The teachers acquire a great deal of knowledge about specific topics that are usually far outside the realm of the usual curriculum. Whatever topic the students choose to study—mathematical chaos and fractals, motion of ocean waves, brine shrimp, nerve muscles, cell regeneration, statistics, or even political science—teachers or mentors usually benefit by gaining knowledge beyond the everyday curriculum. The teachers also have the opportunity to integrate many different aspects of the school curriculum as the students work on the projects and use math, science, technology, computer science, English, and library skills for comprehensive projects. As students begin to study topics more intensely, both the teachers and their students learn about and use the newest discoveries and latest techniques.

Contact with famous researchers is a bonus that may be a natural result of the advanced research students perform for independent research programs. For example, as a direct result of my students' research, we have met Nobel Prize winners, MacArthur fellows, and Sloan Research fellows.

Teachers may also benefit from traveling to student competitions and conferences throughout the United States. The networking opportunities and experiences outside the classroom are often professionally stimulating and personally satisfying.

Finally, teachers discover they are working with motivated students. The students want to be in class, they ask good questions, and they want to learn. In fact, the teachers will not be able to keep the students away from the independent research class!

Benefits to Students

In an independent research class, students learn how to conduct and complete their own independent research projects using the scientific method. They discover that one of the most important aspects of research is the exchange of ideas and discoveries, and they learn how to write a research paper and abstract, as well as other narrative descriptions of their research. They also learn how to present their work to student peers, teachers, colleagues, and scientists.

If the students work in a lab, they become familiar with many types of scientific equipment. Students often receive responsibilities and privileges equal to those of scientists and graduate students working in the research lab. If the students are working on a small part of a very large project, their responsibilities are even greater because other scientists are waiting for the students' results before continuing with the rest of the experiment.

Working on an independent research project can help students determine the kind of work they want to do as adults. Many of the skills that the students learn will stay with them throughout their college and professional careers. The contacts the students make as they meet professionals and even celebrities are also potential benefits.

Student researchers tend to have strong college applications because a project may serve to focus the college application essays. At the same time, independent research projects and competitions can be financially rewarding. Many colleges offer merit scholarships to high school graduates who have worked on independent research projects and have entered the major independent research competitions. And, of course, the competitions sometimes award generous scholarships to the winners.

Students also benefit from the experiences involved with traveling to other cities for the competitions, seeing what their peers are doing, and meeting students other than their schoolmates. One year, my students visited twelve different cities. Sometimes the school district pays for travel; at least half the time, sponsoring organizations pay for travel. Planning fund-raising activities and approaching potential sponsors for travel money are also activities that challenge and stretch students. For several years, my students have created their own "tour" T-shirts that are

not only great fundraisers but also expressions of pride that contribute to community awareness of the program.

A Winning Scenario

Two friends, Ben and Paul, decided to join an independent research class and quickly became involved in all kinds of projects. First, they learned how to build balsa wood bridges. As they worked on their projects, they encountered many problems. Their first bridges were totally disqualified, but they continued their work. Paul entered the math fair. Ben entered the science fair. They joined a team to build a balsa structure for the Odyssey of the Mind competition. Together, they wrote an energy conservation proposal to create an efficient windmill and they each began a major research project to enter in the Intel/Westinghouse Science Talent Search Competition. They combined their research projects with the ideas they used for their original windmill energy project.

Together, they worked on their project with new energy and did a lot of research on windmills. Each built a 1/50 working scale model of a Dutch windmill. Ben and Paul read about and experimented with different blade diameters, increasing and decreasing the width of the blades from the base to the tip, changing the number of blades, adding and deleting a tail vane, and working with different wind speeds. They tested their windmills with many different parameters and created reams and reams of data. Then the data were statistically analyzed. Finally, each student wrote and presented a paper, and entered it in the Science Talent Search Competition.

Did Ben or Paul win the competition? No, neither won a major competition. Yet, they did have a winning experience. They learned a lot about windmills and alternative energy and about building models, making presentations, and writing papers. They became young men who are quite sure of their abilities in the science world. When it was time to apply to college, they had credentials, they had awards and certificates, and they had great experiences! The interaction with professionals helped them approach their college interviews with confidence.

Most of all, Ben and Paul learned that they had the ability to start, complete, and present a major research project. In addition, their experiences proved beneficial to the school and the community. The

experiences that Ben and Paul had through the independent research project, collectively and independently, changed the academic culture in the school as their peers grew to realize that there is more to school than just the required classes and core curriculum. And their work indicated that school work could be fun. As a result of the credentials, confidence, and experience Ben and Paul gained through their research projects, they were accepted by excellent colleges. Local students attending excellent colleges boosted the community's perception of the school district. In turn, this made the community a more desirable place to live. And, within the school community itself, the teacher enjoyed working with enthusiastic students who were genuinely interested in what they were doing. The students wanted to learn for learning's sake, and weren't just learning to perform on a test. The teacher benefitted by talking with experts about the topics under study and traveling with the students to competitions, thereby widening her circle of colleagues to include other research teachers and professionals.

Does it really matter that Ben and Paul didn't win a national contest? No, because just by working on a project they have already won. And so can your students. Your students can discover that to enter is to win!

2 Assessing Your Situation

Before beginning an independent research program in your school or district, prepare yourself with an understanding of how the program fits with current educational practices and what community resources might be available to help your students and mentors. Then assess the curriculum and pedagogy in your schools and school district and how you can merge these with an independent research program.

Whatever methodology your school uses, never lose sight of the primary goal of an independent research program: students working on and completing independent research projects. Within reason, how the teachers and students reach that goal is not important.

How Does Independent Research Fit with Current Educational Practices?

There is no correct methodology for organizing or conducting an independent research course. In addition, there is not a single education practice that the educator must use. Teachers or mentors should use an approach that is comfortable for them and for their students. Although you may experiment with different approaches or even combine approaches, every successful independent research course involves administrators, parents, students, and the community. The teachers, however, have vision, high expectations, passion, and compassion. They risk unorthodox techniques to motivate students.

While assessing your school and situation, it might be useful to think about current educational practices. Several educational practices

and theories work well with an independent research course.

- **Integrated Curriculum.** While working on independent research projects, students use, at the minimum, skills they have learned in math, science, computer, technology, and English.

- **Cooperative Learning.** Students are encouraged to work together as part of a team to take on a large project. The students learn how to break down a large project into parts and to assume various leadership roles. In addition, students share their work with other students and often get help and ideas from other students.

- **Partnerships with Community, Industry, Schools, Colleges, and Universities.** As students look for more information about their projects, they reach out beyond the normal school environment and begin to see the integration of their work with the greater community. Through observation and experience in the community, students learn to use their knowledge and skills in real-world situations, thus preparing themselves to enter the workforce.

- **Constructivist Learning.** Working on independent research projects allows students to pose problems relevant to their interests. Because they look at a holistic project rather than pieces of projects, students structure their learning around primary concepts. They work on projects that value their point of view and they adapt the curriculum to their needs. Finally, the students have their work independently assessed in the context of their experience with the project or experiment. Most research is based on questions that have not yet been satisfactorily answered by anyone working in that field.

- **Mentoring and Coaching.** Rather than standing up and lecturing to the class, the teacher works *with* the students and they try to solve problems together.

- **Flexible or Block Scheduling.** Because independent research projects require intensive study and multidisciplinary undertakings, students need large blocks of time to work on their projects and to meet with teachers in various disciplines. Block scheduling also helps students work successfully as a cooperative group, and allows them to meet with people in the community, industry, and universities. Time for the project is not usually a daunting problem because students are willing to seek help outside of school hours; however, introducing flexible scheduling into the traditional school schedule can be challenging.

- **Contests as Authentic Research Experiences.** Independent research projects encourage students to enter local, state, and national contests that provide tough standards, real-life constraints, and strict deadlines. Students enjoy entering the contests because they can see how they compare with students from all over the United States and the world, rather than just comparing their work with their classmates' work. The focus on external contests causes the students to work cooperatively, rather than competitively, to submit the best projects possible from the school. Focusing on an external competition and seeking to have a winner from the school fosters a sense of team spirit that is stronger and more effective than classmates competing against each other. Students also learn that competitions can be arbitrary in selecting a winner. They discover that the entry they deem the best might not be selected to win and that another entry that they did not think of as highly might actually fit the contest judges' understanding of the standards and become the winner. In this way, students also learn again that to be in it is to win.

- **Personal Best.** Students compare entering competitions to entering a marathon. Although a marathon has only one winner, many thousands of people enter just to prove to themselves that they can complete the task. And the competitors enter year after year to improve their personal best. The same can be said of the research competitions. Students enter the national research competitions to prove to themselves that they can finish a significant independent research project.

Survey Community Resources

It is a good idea to take a look at the research resources that are available to your school and students. First, note the obvious resources: the universities, colleges, and research institutions. Call each of these places and inform an administrator about your independent research program. Ask if you can bring students to tour laboratories and libraries, meet professors and research staff members, and use the facilities.

Second, look to the next level of available resources:

- **Environmental Workers.** Farmers, gardeners, and professional environmental workers can help connect students with other environmental resources in the community.

- Doctors, Nurses, and Health Professionals. These professionals are able to answer questions and help connect students with other resources in the health-related fields. They will be able to help students find independent projects in biology, medicine, and health fields.

- Businesses and Manufacturing Companies. These facilities often have information about their own research and these businesses may be able to help students with computer, engineering, and chemical projects.

- Community Leaders. Every community has some areas that need attention, such as recycling or an environmental clean up. Contact community leaders and politicians for help.

- Teachers. Many subject area teachers have skills that can be extremely useful. In addition, teachers often have many professional and personal connections and acquaintances who can be mentors or offer special information.

- Parents. Parents often have specialized skills and connections that can be tapped for research.

Finally, if you find relatively few resources in the community, search the Internet. The Internet is being used by increasing numbers of students and scientists to ask questions and to find answers and resources. You'll find that some scientific journals are published solely online (two examples are *Social Science Research Network* and *World Wide Web Journal of Biology*).

After surveying community resources, create a pamphlet of the findings for yourself and your students. Make a list of potential mentors, available equipment, and types of ongoing projects. Include journals, professional societies, and Web sites. As students work on their projects, ask them to update the information for other students to use.

3

Practical Considerations for the School

There is no one perfect way to set up a program. Assess available resources, including teachers, space, students, budget, and community assets. You may wish to start with a small program, such as an after-school club or a before-school activity, and let that program gradually grow larger. Although you can model your program after another successful program, don't be afraid to create a program that follows one of the models or create a unique program by combining components of several models. Most schools begin modestly and allow the program to grow. Because independent research programs are community-based, each is unique.

Keep in mind that most student research is conducted outside the school at research labs, colleges, industrial sites, libraries, and hospitals. An important part of a good independent research program is allowing students to work off campus, giving students the experience of a research career while in high school.

Program Models

Common models for independent research programs are given below. Use the information as a guide for adopting or rejecting whole or parts of the models. Pick out the aspects that would best suit your situation to create your unique program.

Lunch Period. Teachers meet with a few motivated students several times a week during student lunch periods. While eating lunch together, the teachers provide information about the science of research

and the various student research competitions, as well as details about writing and presentation skills. In the relaxed atmosphere of the lunch period, students feel free to discuss and review their papers and practice their presentations. Lunch period classes should meet only one or two days a week because students still need their own free time. The teacher is usually granted one or two fewer regular classroom-teaching periods or is relieved of a duty for this assignment. Some schools grant the teacher additional pay.

After-School Club or Before-School Club. Teachers meet once or twice a week with students who are interested in working on independent research projects. The teacher is able to follow the independent research curriculum because this arrangement is more formal than the lunch period program. The club atmosphere is more conducive to focused work on projects than the lunch period arrangement when students are easily diverted by eating and socializing. The time allowed for a club period is usually longer than a lunch period, too. During club time, students are able to work on in-school research projects and to make formal presentations. A formal club structure allows the teacher to help the students focus on the work, to help with projects, and to provide a place for students to keep their work. The teacher receives compensation according to the academic club pay of the school district. A big drawback of after-school and before-school clubs is that students do not receive formal grades or credits, therefore many students treat the independent course less seriously than they should.

Outside Consultant. Sometimes a district does not have a teacher who has the background to direct or teach an independent research program. In that case, the school district usually hires a consultant to work as a mentor with the independent research students. The consultant informs the students about the independent research curriculum and helps the students with their projects. In addition to working with students on their projects, the consultant provides instruction on writing and presenting research papers. Usually the consultant trains a teacher to take over the program after the first or second year. The consultant can be a recently retired teacher, a professional researcher, or a visiting professor. The consultant is typically paid an hourly fee by the school district.

Semester Courses. Some schools divide the independent research program into two separate semester courses that are part of the regular school day. The first course deals solely with the techniques of research, and the class typically consists of 15 to 22 students (see Chapter 5 for a list of topics that should be covered during this semester). In the second semester, students who successfully complete the first course begin to work on independent research projects. They are divided into groups of 4 to 7 students and each group is placed with a different teacher. Students take this course for as many semesters as necessary to complete their research. The school must be able to allow three or four teachers to have one of these small but demanding sections in their teaching schedule (see Chapter 5 on curriculum for a list of topics that should be covered).

Full-Year Program Combined with Science or Math Courses. In this independent research program, students are assigned to work on independent research projects as part of the science or math curriculum. Students work on their projects, including writing and giving presentations, as part of class and lab time. Because many research projects are in science or mathematics, this program accommodates the majority of the research students. Students usually need time outside class to complete their projects. A full-year program that is combined with the curriculum is part of the teachers' regular assignment.

Release Time from School. In these programs, students have a schedule that leaves them free of regular classes at least two or three half-days each week. Some juniors and seniors have the flexibility to do a morning or afternoon program, provided they get credit for the research program. The students are then given release time to work on their independent research projects in hospitals, universities, and industry. Release programs are usually combined with a teacher and mentor program. Students meet with their teacher or mentor at the school to review their progress and to discuss information about various competitions. The teacher also provides instruction about research methods and the methodology for writing and presenting research papers. Some schools offer students as much as two credits for an independent research class (more than for a regular class) because of the time commitment. The structure of a release time from school program is similar to a work-study program.

Independent Research Class. In this model, a course within the school curriculum is dedicated to independent research projects. The course is usually incorporated into the school day. Students learn research methods, master some basic statistics, work on independent research projects, and receive instruction on how to write and present a research paper. The teacher helps students with all types of independent research projects: science, mathematics, social science, and English. This is a regular teaching assignment. In schools with a large and active research program, the teaching job can be a full-time assignment. This model can be found in many New York school districts.

Separate Independent Research Classes for Different Areas of Research. In this model, the school provides separate teachers for each of the independent research areas offered—for example, a math research teacher, science research teacher (which may be subdivided into biology, chemistry, and physics), and social science teacher. Students must select one area of research to concentrate on. The independent research class is part of the teacher's regular teaching assignment for one period per day.

Class Period After or Before School. In this model of an independent research program, the school accommodates students who already have full schedules by creating an extra period, either before or after school. The independent research class is a regular teaching assignment; the teacher's hours are usually modified or the teacher is paid for teaching the additional class.

Individualized Classes. Some independent research classes are very individualized. Rather than meeting every day of the week with the whole class, the teacher is given the flexibility to meet one-to-one with students before school, after school, during lunch, or in pull-out programs similar to those some schools use for music lessons. One-on-one meetings are often held at times the student and teacher are both free. Sometimes these meetings take place when a student is given release time from class. The schedule for these classes must also include the teacher meeting once a week or once every two weeks with the whole class. During whole-class meetings, the teacher discusses upcoming assignments and students critique each other's presentations. Individualized classes are part of a teacher's regular teaching assignment.

Create a Budget

Although the commitment a school district makes to the creation of an Independent Research program is unique and does not need to be extremely costly, it will entail some expense. It is important to plan a budget before you initiate the independent research projects course. After the course has been approved, the district supervisor, the principal, and the teacher should get together to create a budget. First, it is important to obtain answers to the following questions:

- Which independent research program model does the school or district plan to adopt?
- How will the independent research course fit in the present school organization? Will the program be part of a particular department, such as the math or the English department? Or will the program be part of the extracurricular activities? Will the program be handled by central administration?
- How will the budget be allocated? Where will the extra funds come from? Will the program be funded through the various departments, general school funds, or district funds?
- What research equipment exists in the school district? How much more is needed?
- What computer equipment exists in the school district? How much more is needed?

Next, assess the costs associated with the curriculum that you have selected. Determine the costs that are likely to occur with the commencement of an independent research program:

- **Entry Fees:** Most of the national competitions do not have entry fees. Certain local and regional competitions, such as a science or math fair, often have entry fees.
- **Travel Fees:** The students and mentors or teachers need to travel to the local and regional competitions. Even if your school does not have an entry the first year, it is important for the students and their mentors to see the kinds of projects that they aspire to complete within a year or two.

- **Supplies:** The students need laboratory supplies for their projects, poster boards for project displays, and normal classroom supplies. The students, however, are expected to obtain some of the commonly available supplies.
- **Computer Equipment:** Students should have access to computers, printers, scanners, modems, and a variety of software so they can write reports, create spreadsheets, graph data, prepare statistics, make presentations, gather information from the Internet, and communicate with fellow researchers using e-mail.
- **Photocopying Equipment:** Students will need this equipment for research and presentation.
- **Laboratory Equipment:** Students will need to share science equipment with the science lab courses or have some of their own equipment.
- **Textbooks:** Students will need manuals to help them use their software and texts to explain statistical methods and special concepts.

After you have assessed expenses and created the initial budget, it is important to create a three-year plan so that the larger expenses can be distributed over time. For instance, you may ultimately require five computers, but you can get the program running with only two the first year. At the same time, look for grants from the PTA, teacher centers, local businesses, and national corporations. Grants can be in the form of supplies, money, and new or used equipment.

Find Facilities

The next major practical consideration is space. If your school decides to set up a serious program, it is important to create a friendly and nurturing environment for the students because independent research projects require a lot of time, energy, and dedication from both students and teachers. At a minimum, the students and their mentors need a meeting place. Ideally, the meeting place is a dedicated area that includes a research laboratory and storage, along with access to computers, the Internet, and the library.

A room dedicated to the independent research program is a place where students can meet, write, create posters, use computers, duplicate

materials, and meet with their teacher or mentor. The room does not need to be equipped with a great deal of scientific and mathematical paraphernalia, but it does need to be a comfortable place that encourages and supports students in their work. Specialized labs and equipment are usually available to students through their work with mentors outside the school in industry, research laboratories, or local colleges and universities. Students who are working on in-school projects should be able to use the school's rooms and equipment during free periods or after school, or the students should have some space dedicated for their use. The following types of spaces can be used for an independent research program.

Dedicated Classroom or Meeting Room. A dedicated classroom or meeting room gives the students and their mentor the flexibility to meet in a group or one-to-one. A dedicated space allows the teacher to meet with groups of students in a place that has access to the books, supplies, materials, and computers used in the various research projects and allows students to work on their projects without worrying about the bell. Incomplete posters or papers can be left until the students can return to them later in the day or the next day. The area can be set up to look like a regular classroom with student desks, plus an area with large worktables or a lounge. Ideally, the room should be a combination of workroom, computer lab, storage area, and lounge. The room should be convenient for and accessible to students before, during, and after school.

Computer Lab. Some possible locations for the computers include a dedicated research classroom, school library, dedicated computer lab, or some combination of these possibilities.

Storage Area. Students will need a place to store their projects, equipment, and posters. At the minimum, this area can be a storage closet anywhere in the school. Ideally, the storage area should be attached to a dedicated student research classroom.

Supplies and Equipment. The full range of necessary scientific equipment will depend on the teacher's field of expertise and the students' interests; a basic set-up typically includes the following:

- Telephone: A telephone is needed to contact outside mentors, universities, industries, and suppliers.

- **Computer:** A computer is necessary for writing research papers, completing applications, using the Internet, and working with software packages. At a minimum, the software should enable students to create charts, graphs, and view graphs (overheads) for presentations; use sophisticated statistical techniques; and work on mathematical models.

- **Modem:** A modem is necessary for using e-mail and the Internet to contact libraries, universities, mentors, and researchers all over the world who have the same research interests. Many of the research competitions, such as the Intel Science Talent Search (formerly Westinghouse), the Intel International Science and Engineering Fair, and the Duracell Scholarship Competition have placed their applications on the Internet for easy access. And, of course, a modem is essential for competitions such as the ThinkQuest Competition, in which students are asked to create Web sites.

- **Fax Modem:** The students and teachers will receive many faxes in conjunction with their research; a modem replaces the need for a fax machine. One of the most common uses of the fax modem is to receive and send the many approval forms necessary to carry out independent research projects.

- **Printer:** A printer allows students to print their papers, charts, graphs, and view graphs. The printer even enables students to print banner title boards for their presentations.

- **Printing Supplies:** Some special paper supplies include computer-printable view graphs, banner paper for poster title boards, and glossy paper for printing photographs.

- **Poster Board:** Keep a supply of poster boards or project boards on hand for the students to use so they will have high-quality posters of the correct size and format. The best type is foam board in the triptych style. Also maintain a separate supply of title boards to go with the posters.

- **Laboratory Supplies:** The types of supplies needed depends very much on the projects the students begin to work on. Rather than ordering supplies in advance, allocate a budget for supplies and purchase them during the school year.

4

Practical Considerations for the Teachers

Independent research teachers work to support students to create the best possible project for each student; thus, the teachers work as mentors or coaches for the students rather than as lecturers or teachers. Although independent research teachers provide support and help to the students, they must not provide a step-by-step project plan for students to follow. One of the primary tasks of research teachers is to show students where to find the necessary information and how to assess the information. Independent research teachers teach their students how to establish a schedule, how to follow a set of competition constraints, and how to finish the project on time. The first task, however, is to identify students who want to pursue an independent research project.

Recruiting and Selecting Students

I cannot emphasize enough that you need to look beyond the students with the highest grades. The students who do well in an independent research course are those with perseverance, initiative, and motivation. The easiest way to find these students is self-selection—a simple and effective policy. Students who are interested in research and who are willing to work will sign up for the course; students who are in the course simply for the fame and glory of winning a national competition will not stay in the course once they see the amount of work involved. Students with average grades but with a passion for a research topic can and will do extremely well. I have had students ranked in the bottom third of their class write excellent papers and receive national recognition for their work.

You may need to limit the number of students in the research program because of available space or budget, or because the district believes that certain criteria will identify successful students. One school district restricts the number of students who may participate in their program to only ten new students each year. The application process is extremely rigorous. Students are selected on the basis of personal interviews, grades, and scores on standardized tests.

If your school district goes with a selection process rather than having the students self-select, it is important to make the process fair. If you have a selection procedure for students to enter your independent research course, it is important to leave a door open for the student who does not quite "fit," but has a real passion for a specific research topic.

A Case Study in Selecting Students

In the Three Village School District in Setauket, New York, a districtwide committee selected 35 students each year for entry into the independent research program. The application process was quite thorough, requiring a one-page autobiography, a two-page science topic essay, a copy of the student's transcript from 8th and 9th grades, and two teacher recommendations. The names and all identifying materials were removed before the applications were reviewed, then a committee of teachers and administrators read and graded the student essays. All scores were put into a rubric designed for the process, and the top 35 students were selected for the program (see figures 4.1, 4.2, and 4.3).

FIGURE 4.1

Rubric for Selecting Students for Independent Research Programs

	8th grade Science	8th grade Math	8th grade English	9th grade Science	9th grade Math	9th grade English	Teacher Rec 1	Teacher Rec 2	Auto- biography	Science Essay	Total
Student 1	B+	B	A	B+ (H)	B+ (H)	A (H)	3	4	3	3	23
Student 2	A	A+	A	A (H)	B+	A+ (H)	4	4	4	4	47

Student grades are averaged for a final score. A grade followed by (H) indicates an honors class.

Student Grades. The student grades from math and science were part of the assessment because most of the projects were in those disciplines. Grades in English were included because writing skills were critical for the research papers. The students' performance in math, science, and English were plugged into Figure 4.1 using the scoring rubric in Figure 4.2.

FIGURE 4.2

Scoring Rubric for Student Grades

	Honors Course	Regular Course
A+	4	3
A	3	2
B+	2	1
B	1	0
C+	0	0

Teacher Recommendations. Each applicant selected two teachers to fill out the scoring rubric shown in Figure 4.3 (p. 22). The resulting scores were inserted in Figure 4.1 (p. 20) as another step in selecting students for the Three Village School District's program. The teachers gave scores according to how they perceived students to rank among their students during that school year.

Autobiography. Each student wrote a one-page, double-spaced autobiography that included science and math interests and achievements. Essays were scored from 1 to 5 by a selection committee. A minimum of three people read each essay.

Science Essay. Students were also asked to write an essay on any science topic, using the following guidelines:

- Write an essay discussing a scientific development, event, or theory that has captured your interest and attention.
- The essay must have a title.

- The essay must be an original manuscript written exclusively for this application.
- Include a bibliography. Do not attribute encyclopedias.
- Attribute all quotes and ideas that are not your own.
- Limit your essay to two double-spaced pages. Do not use special fonts (nothing extra small or fancy).

Essays were scored from 1 to 5 by a selection committee. A minimum of three people read each essay.

NOTE: Although not all the students proposed topics in science research, we found the science essay useful in assessing student abilities and knowledge in scientific research methods.

FIGURE 4.3

Scoring Rubric for Teacher Recommendations

	Average or Below Average	Good (Above Average)	Superior (Top 30%)	Excellent (Top 10%)	Outstanding (Top 3%)
Perseverance	1	2	3	4	5
Initiative	1	2	3	4	5
Dependability	1	2	3	4	5
Thoroughness	1	2	3	4	5
Intellectual Potential	1	2	3	4	5

Teaching Techniques

An independent research class is not the same as most other high school classes. There are no lectures, and even the group work is quite individualized, since each project is unique. Remember that the projects can and should be from all academic disciplines. A highly successful independent research program should have projects from the humanities, linguistics, psychology, biological sciences, physical sciences, computer science, engineering, and mathematics.

It is best to divide the class time into group and individual sessions. A good technique to use for an independent research class is to use the first few minutes of every class for announcements of an upcoming activity, field trip, or deadline. These brief announcements should be reiterated in a format for all the students to see and read on their own time, perhaps through a class bulletin board or calendar. Group instructions on selected procedures might occasionally require more time but most of the class time should be spent on individual meetings with students. The students should bring their journals (see Chapter 5) to these meetings and students and teacher should be prepared to review the work and discuss plans. The mentor should help each student overcome obstacles and find solutions to the problems that the students encountered in their project.

One or two days a week, some independent research teachers choose to teach students some common research techniques, such as statistical methods, research writing, and research presentation. It is important to identify topics that are useful to all students, not just those working in one or two disciplines. The students will learn specific techniques such as how to prepare microscope slides in their individual research labs. In fact, even if students know how to use a sophisticated piece of equipment, the labs will reteach that skill because they want students to follow their specific techniques and safety procedures.

Another important task for the independent research teacher is to help the students to make connections with outside mentors both in colleges and industry. The teacher is the first point of contact for most students. An independent research teacher helps students solve problems associated with the actual research and the completion of research projects. Thus the teacher is involved with, but is certainly not limited to, making telephone and Internet connections, setting up links between the high school and the outside world, and coming up with creative solutions to all the problems that students encounter while working on research projects.

Grading Policy

Every research course should have clearly defined objectives and a grading policy that are presented to both students and parents at the

beginning of the school year. The course grade should be an average of the grades the students have received on their various projects. The project's grade is dependent upon meeting the course deadline, preparing research papers in proper format, and addressing the requirements of competition. How an individual fares in a competition should have no bearing on the course grade.

A research teacher needs to be serious about helping research students always try to do their best on every assignment. Each student's grade depends not on the project idea but on how the student researched the idea, wrote the paper, and made the final presentation. Students in an independent research course should demonstrate excellent work in the following areas:

- **Hypothesis:** Students should be able to formulate a hypothesis and protocols for their research.
- **Planning:** Students should be able to create a time frame for their research. They should be able to organize and schedule their time to finish the project according to the various competition deadlines.
- **Entry in Contests:** In addition to pursuing their research, students should enter at least one science fair or similar contest each semester. Entering projects in contests prepares students for the major social science, math, and science competitions and also helps them to enhance their skills in developing their work for presentation. In addition, many contests offer students the opportunity to have their work evaluated by experts in their research field. The motto of independent research, "To be in it is to win," means that a great deal of emphasis is placed on preparing excellent papers that meet all the requirements of the various competitions, rather than just celebrating the successes. How an individual fares in a competition should have no bearing on the grade for course.
- **Essays in Scientific Form:** Require students to prepare work using the correct form for academic essays and papers. Prior to the course deadline, each student should be given the opportunity to have the paper critiqued by a peer group, as well as by the research teacher. The student should be able to resubmit the corrected paper for a grade. In fact, students submit several drafts, all of which are graded. The final grade for the project's paper is the grade given on the final draft. The

paper should be graded prior to being sent to the competition. Thus, the grade is not dependent on how the paper fares in the competition.

- Oral Reports: Students are periodically required to deliver oral reports to their classmates. As with the entry in contests, oral reports help students hone their skills in preparing their material for presentation and evaluation by others.

- Statistics: One of the facets of the course is the teaching of statistical concepts deemed appropriate and necessary to the goal of carrying out scientific research. Statistical methods are necessary for most of the social science projects, as well as projects in the physical and biological sciences.

Identifying Projects

Students can work on projects in any area of research; no topic is ever the "wrong" one. A project can come from any curricular area. My students have worked on successful projects in linguistics, the biological sciences, the physical sciences, mathematics, economics, and the social sciences. It is all right if you, the teacher, are not an expert in your students' areas of research. In fact, it is even better if you are unfamiliar with a student's particular area of research because you can participate in the project as a teacher and mentor without previous bias or preconceived ideas. Also, outside mentors can be identified to help with some aspects of the project. Projects can range from the seemingly simplistic, such as *Observations in Toy Stores* or *Creation of a Battery Powered Page Turner* to the apparently complex, such as *The Role of the Conserved Carboxy-Terminal WRPY Motif in Transcriptional Regulation by Runt-Domain Proteins* or *A Study on Protease-Antiprotease Interactions and the Use of Green Tea as an Elastase Inhibitor*.

Think small, not big. Since the research assignment is part of an independent research program that is above and beyond regular schoolwork, the project will be something a student is really interested in. In fact, students continue with the project only when they become dedicated to or even passionate about their topic. An independent research project is work that a student does for himself, not for anybody else. Completing a research project takes many hours of work both inside and outside of school. A common mistake of many students is to iden-

tify far too large a topic for their research. It is here that the teacher and mentor can help by showing students how to narrow a project to one that is manageable yet substantial. For instance, one student began a social science project investigating how adult children of Holocaust survivors were influenced by their parents' experience. She soon found that there were hundreds of dimensions to this inquiry and that she had to limit herself to a selected few, such as education or child-rearing practices.

Students will be working on their experiments, setting up the project, collecting data, and analyzing data. If they do not like their projects, indeed enjoy them passionately, they will not complete them. If students are working in areas that interest them, however, the endless hours will be fun and enjoyable.

Getting started on *the* research project that your students plan to enter in the national competitions, such as the Science Talent Search or the International Science and Engineering Fair, can seem a daunting task. In truth, it is rare to wake up one morning and say, "I know the project I want to do." Many students have no idea how to identify a project topic, much less a very specific science research project. They often know only that they want to do research in a general area such as mathematics. Typically, the more students see the kinds of independent research experiments that both professional researchers and other high school students are involved with, the easier it becomes for them to discover the specific research that they want to pursue. Here are some ways that you and your students can get started in the world of research:

- **Read Related Materials.** Have your students choose a broad topic. Then go to the library and the Internet and research the subtopics within the main subject area. Review professional journals and magazines, as well as books, Web sites, and textbooks. As students read, do not have them look for a specific project or experiment, but rather ask them to read to gain background information about their general area and the research that has been conducted. Also, have them become familiar with the famous scientists in the field.
- **Attend Lectures.** Find out about the academic lectures, symposiums, science fairs, and conferences in the area and go to as many as possible.

- Visit Professional Facilities and Institutions. Visit as many local industries, utility companies, museums, and academic institutions as possible. The computer department, quality control, and the design and engineering departments of local companies are interesting areas to explore.
- Look into Student Science Programs. Discover the student science programs in your area. There may be Saturday morning workshops, lab experiences, lectures, or courses for high school students.
- Investigate University and College Departments. Find out about the various departments at nearby universities and colleges. Students and mentors can speak with professors in the disciplines that seem interesting and applicable to student projects and research. Do not be afraid to call or schedule a visit. Many professors are glad to discuss their experiments or research, and they often invite research students and mentors to visit their labs and help work on an experiment.
- Discover University and College Courses. Find out about the kinds of courses offered at local universities and colleges. Students may be able to take a course there, either to learn about a new area or to enrich their knowledge about a certain topic.
- Research Summer Programs. There are many summer research programs throughout the world. Science Service publishes an annual listing of all the research programs throughout the United States (see Appendix III).
- Network with Parents. Parents may have connections to industry, colleges and universities, and other places that may offer research opportunities. Do not be afraid to ask.
- Find Mentors. Survey the people in the community to identify those who can help your students with projects. Teachers and others may have advanced degrees in specialized areas or have particular interests. Mentors can also be found at universities and in industry.
- Invite Speakers. Invite professors, scientists, researchers, or older students to your meetings to discuss their work and careers. Student guest speakers could talk about their projects and their experiences at research competitions.
- Sponsor Brainstorming Sessions. The program members can pool their ideas for independent research projects. They can share their pro-

jects with one another, discuss the successes and failures that they have encountered, solve problems together, and present their results to one another.

- **Work on a Major Project Together.** Each student is responsible for one small aspect of the project, so that at the end they have completed an extensive project beyond the scope of a single person. Several student clubs, for instance, have successfully built telescopes and robots.

- **Discuss Current Events in Math, Science, or Social Science.** Supplement discussion with related slides, films, and videotapes.

- **Host a Competition.** This could be a small competition just for the members of the class. Or host a major fair for your entire county or region. If your school or community already hosts a fair or other competition, club members could help set up and host the fair.

- **Use Student Mentors.** Members of the independent research program can visit the elementary and junior high schools as well as classes in their own school to give lectures and demonstrations. Students can discuss their experiments and their experiences participating in independent research competitions. In addition, they can show other students how to make presentations, how to create good posters, and how to get started on their own science research experiments.

- **Publish an Academic School Magazine, Yearbook, or Newsletter.** This student publication could contain student entries, articles of general academic interest, winning academic research project papers, puzzles, and other items of academic interest.

- **Initiate a Neighborhood Project.** Students could work on a major activity for the neighborhood or community. Some projects to consider might be cleaning up a lake, preserving wildlife, or establishing an organic garden.

- **Host a Community Night of Research.** Some independent research programs sponsor regular evening presentations at which students, scientists, researchers, professors, and industrial leaders discuss their completed research projects, current projects, and careers. Community nights allow students and scientists to meet and exchange ideas about science projects and areas of expertise.

- **Encourage Passing Down Projects.** Seniors who have finished their projects can pass down their projects to younger students. Passing down projects can work in several different ways. Sometimes the

younger students use the "old projects" as jumping off points or for inspiration to begin their own research along different lines. In other instances, the younger students continue the project or choose to replicate the project for verification.

Identifying and Defining Mentors

A mentor is an excellent asset for any independent research project. The mentor is usually someone from industry, academia, or a professional organization who brings an expert's viewpoint to the project. The mentor may allow students to work as assistants in a research environment, invite students to professional conferences, help students to understand concepts and formulas, provide access to state-of-the-art equipment, and assist students in selecting meaningful and achievable projects. The most common form of mentorship occurs when a student works directly with a mentor on a mutual project. Both the mentor and the student work on separate parts of the project toward a common goal. Sometimes a student works on a project that is not directly related to the mentor's overall goal. The student's project may shed new light on techniques or different aspects of the project. In other arrangements, the student works with a graduate student in the mentor's lab, with the graduate student acting as a link between the mentor and high school student.

Students can be successful with part-time mentors, phone mentors, or even Internet mentors. Sometimes a student just needs an answer to a specific question. For instance, one of my students was interested in studying the shift in population centers in the United States. He was not quite sure that he had correctly set up all the project parameters, therefore he called a mathematician at a local university for advice. After a 10-minute telephone call, the student was confident he was on the right track. He finished the project and became a semifinalist in the Intel/Westinghouse Science Talent Search. Later, when he called to thank the professor, the professor said that he could not remember the conversation. To the student, however, this conversation had been crucial.

Mentors can also help students meet other professionals in the field and develop a network of contacts. The mentor can help students locate colleges with similar research projects and sometimes even help with

college placement, either through professional contacts or by writing letters of recommendation. In a few cases, the mentor becomes a lifelong friend.

Students should not contact a mentor and just ask for a project or to work in their lab. Instead, students should already have a potential project in mind and should have conducted some preliminary research before they begin to look for a mentor. When students contact a potential mentor, they should be prepared to do the following:

- Discuss their independent research project and how their research ties in with the mentor's work.
- Discuss problems and possible solutions.
- Ask if they can use specialized equipment not available in their school.
- Ask if they can take a lab tour.

Here are some suggestions for students and teachers to use in seeking independent research mentors for specific research projects.

- Read the work of researchers who have worked on similar topics and contact them.
- Use e-mail, the Internet, or the telephone to contact professionals in local universities and industries who have worked on similar research topics. Discuss the project with them and ask about working with them.
- Attend professional meetings in the area of research.
- Attend science fairs, symposiums, and conventions related to the independent research topic. Discuss the project with the participants and professionals.

5

The Curriculum

This chapter examines topics that should be covered in the formal part of an independent research course. It includes important components of the research project and tips on writing and presenting the independent research project. Use this section to answer the how-to questions your students pose and to anticipate snags in the presentation process.

Defining an Independent Research Project for Students

How is a research project different from a model or a report? A research project must be an experiment rather than a simple written report or a model. A research project involves defining the problem, researching the problem, setting up an experiment using the scientific method, conducting the experiment, collecting the data, and analyzing the data. To that end, students must understand the scientific method and how to use it as a basis for their independent research project.

Using the Scientific Method

Students must fully understand and appreciate the scientific method for problem solving, which is the primary method used by most researchers. The scientific method is based on the following six steps:

1. Define the problem or project. Whether students want to clean up a local park, do an in-depth study of high school students' rights,

study the effect of religiosity on healing, or work on a traditional science or math project, they must establish a clear set of goals and objectives. These goals and objectives are among the first entries in the official research notebook that students set up for each project.

2. Research the background of the problem or project. The research should take many forms in addition to the traditional library encyclopedia research. Encourage students to use the Internet, read periodicals, and contact and interview experts in the field for the latest information on their topic. Whenever possible, students should seek and work with primary resources (e.g., an article written by the expert rather than an article referring to the expert's article).

3. Design a procedure or an experiment to carry out the problem or project. The students use all the information they have gathered to create their independent research project plan, a plan that will either yield a solution to the problem or show why no solution was found.

4. Start the project or experiment. As students work on their projects, they should use feedback to make necessary changes in their procedures.

5. Analyze the data using statistical methods or the most current and useful methods in the field of research whenever possible. Encourage students to use computer programs to analyze data. Many computer programs are not only easy to use, but allow students to use sophisticated statistical techniques. The computer programs also make it easy for students to create graphic displays for their poster presentations and papers. Some computer programs with statistical functions include Microsoft Excel, JMP IN, and software from the SAS Institute or SPSS statistical software.

6. Share the results. Students should be encouraged to share their results in many different ways: giving a formal presentation, writing a paper for publication, or creating a poster or view graph presentation.

Keeping a Research Notebook

A research notebook is simply a notebook that becomes the student's resource book and journal. Choose a hardbound notebook to ensure that the pages do not get lost or use a lab notebook with graph paper pages (the graph paper helps with calculations and graphs of lab

data). Students should be strongly encouraged to keep all project notes in the notebook. One of the earliest entries will be a list of contacts and all the books and articles read on the topic, along with a short summary of each. The notebook becomes a diary of the daily and weekly progress of the independent research project. When students are ready to write and present their papers, a well-organized notebook will expedite the task.

Using Statistical Methods

After students have completed their research projects, they must be able to organize, analyze, and interpret the large amount of data they have collected. Researchers turn to statistics for help in determining if the observed differences in data are meaningful. A software program may be a useful tool for students.

Descriptive statistics describe measurable characteristics of data. Some examples are the mean, range, percentile rank, standard deviation, and correlation. Descriptive statistics also include the following:

- Graphs and tables that are pictorial representations of data.
- Measures of central tendency include the mean, median, and mode. Although these three measures are calculated quite differently, they are interchangeably referred to as the average.
- Measures of dispersion include the range and the standard deviation; they describe the spread of the scores from the highest to the lowest.
- Correlation and regression describe relationships between pairs of variables.
- Inferential statistics allow researchers to make inferences about a population from studying a small portion, or sample, from it.
- Sampling refers to looking at a small portion or sample of the total population. Two examples of samples are the people who have had heart transplants at the local hospital and the 16-year-old girls in the 10th grade in the local high school.
- Statistical testing refers to discovering whether the observed differences in the data are true differences (i.e., significant differences). The t-test, z-test, and the Chi-Square test are examples of statistical tests.

Writing Papers

Once students have completed their independent research projects, the most important research component remains the communication of their results and findings through research papers and presentations. Research papers are usually arranged in the following way:

- **Title:** The title must be self-explanatory; that is, anyone reading the title should be able to clearly understand the purpose of the experiment without reading the paper itself.

- **Abstract:** This one-paragraph summary of the entire paper must include the hypothesis and major conclusion. The abstract is the advertisement and sells the paper to readers.

- **Introduction:** The introduction is the statement of hypothesis and contains the background information concerning the problem. This section clearly states the problem or hypothesis so that readers can understand the question or questions the project or experiment is designed to address. A review of related literature typically provides the reader with the background information or history that goes with the problem. Whenever possible, use primary sources with proper references.

- **Methods and Materials:** This section is a detailed description of how the work or experiment was performed, including a description of the specific materials and methods that were used. The description must be exact and complete so that anyone can repeat the experiment; therefore, this section includes the experimental design, the apparatus, the methods of gathering data, and the control used. In addition, if specimens were part of the study, this section discusses where and when the material was collected.

- **Results:** This section describes what happened after completing the experiment. The results are simply stated for readers to peruse. No interpretations, conclusions, or value judgments are included. If possible, the results should be presented in a graph or table accompanied by narrative text. Each graph or table must contain a self-explanatory title and enough information to fully describe the results presented. Tables and graphs are correctly labeled and titled if they are completely understandable when removed from the paper.

- **Discussion:** This section explains what the results mean. It

describes any patterns that emerged, any relationships that appeared to be meaningful, and any correlations that were discerned. It also describes the reasoning and logic that brought about the conclusion. The discussion can often be accompanied by a statistical analysis of the data. If the results differ from the hypothesis, an explanation should be offered (e.g., the timer broke, a chemical wasn't added). The discussion should also explain why the results were either different from or similar to any related experiments done by others. Discuss the complications that arose during the experiment (e.g., the cells stopped growing, the silver stain would not take), and suggest further research that might be conducted in the same area of experimentation.

- **Conclusion:** The conclusion is a summary of the important discoveries that occurred while working on the experiment and conducting the research. In a sense, this section is a recapitulation of the Discussion and Results sections; it should briefly list important conclusions and discoveries without giving the reasons.

- **Literature Cited:** This section is a list of all references cited in the paper, listed in alphabetical order by author. Use an accepted standard form for listing the references; often one form is preferred or identified by the competition being entered or the research mentor.

- **Acknowledgments:** This section may be used to thank the people who have helped with the research. Acknowledgments are not necessary, but they are always appreciated.

Presenting Papers

After students have completed their experiments and written their papers, they will often be invited to make a presentation about their research. In fact, many competitions require presentations. The presentation is an important aspect of the total project. It is not enough to conduct an experiment and write a good paper; students must also be able to communicate their results to others. They must be able to extract the most important facts and figures and present these ideas and findings so that many people can understand the significance of their results and conclusions. The presentation must be carefully planned and outlined. Unless a particular competition dictates otherwise, students should break their talk into three parts:

1. Introduction. Tell the audience exactly what will be presented to them within a few minutes. The introduction is a summary of the abstract.

2. Body. Inform the audience of the important results or conclusions. Students should be clear and concise and not offer too many details of how they conducted their experiment. Unless the audience consists entirely of experts on the topic, students should not include technical jargon. A good section of the research paper to paraphrase for this part of the talk is the Conclusions section.

3. Conclusion. Give the audience two or three sentences to summarize the project. Simply summarize the results and conclusions of the project. "In conclusion . . ." is a simple way to begin your conclusion.

Presentation Aids

Slides or view graphs are commonly used for presentations to large audiences, while posters are used for presentations to small groups.

Poster Presentation. A poster presentation is a display showing photographs, graphs, tables, and figures relating to the students' projects. When the students make their displays, they should keep the following points in mind:

- The display makes an immediate impact on the judge or audience. Everything on the poster should be planned and created well before the presentation date. The goal is to create an attractive, informative, professional poster. Select coordinating backboards, title boards, and background colors; create all lettering on the computer or using professional lettering methods. Wherever possible, use color to enhance the presentation.

- The posters must be self-explanatory. The audience should be able to look at the displays and understand a great deal about the project before the oral presentation begins.

- The students can and should use their posters as an outline for their presentations. Use the poster to give the talk without an outline or note cards. Make certain that all of the material on display is used or mentioned in the talk.

- Every item on the poster should be simple and clear. Each picture or table should address a single theme and be clearly labeled.

- The students should have a copy of the research paper, the original journal notebooks, documentation of computer programs, and any other relevant materials with them. If it is relevant to the project, students should run the computer programs for the judges. These items may be used as part of the presentation or to help answer questions.

One-to-One Presentation. Quite often poster presentations involve one student and a single judge. Usually, the student is allowed between 10 and 15 minutes for the presentation. It is important to use the time wisely. The first 2 minutes are the most important. In that time, the student must impress the judge with the quality of work and the conclusions.

The presentation must be carefully planned and outlined. Although an excellent presentation appears to be spontaneous, it is important to stress to the students that it is precisely organized and coordinated. And most important of all, students must practice their talks.

Like the paper, the talk needs to be broken into sections; it should have an Introduction, Body, and Conclusion (see section on Presenting Papers earlier in this chapter). Remind students to look directly at the judge (not just at the poster display), to maintain eye contact, to relax, and to try to smile as they make their presentation.

Presenting from a Podium to a Large Audience. Students must set their talk to the audience level. If they are talking to fellow students, they have to explain many of their scientific terms, though they will not have to do that for a group of professionals. They should always remember to speak slowly and carefully.

It is a good idea for the students to use view graphs or slides to help explain their talk. Each slide or view graph should contain only a single idea or theme. The font should be large enough for viewers in the back of the room to read easily. A simple method to ensure that the font is large enough is to place a copy of the view graph on the floor. If you can easily read it standing up, then the font is large enough. The view graph must be self-explanatory; the audience should be able to look at the view graph or slide and understand the sentence or concept before the presentation begins. Tables or graphs that appear on slides or view graphs must be clearly labeled and titled. The accompanying talk should

underline and deepen the audience's understanding of the visual aid.

Many times, the slides or view graphs constitute the outline of the talk. Students should be able to move from slide to slide without hesitation. The use of view graphs or slides should free students from the need to use a separate outline or note cards.

Make sure that students know how to use the remote control for the slide projector. They should practice with the projector before they give their talk to make sure it is working and to become familiar with the idiosyncrasies of the particular machine.

When students are using view graphs, they should not stand next to the projector. Instead they should have another person place the view graphs on the projector. The student presenter should stand near the screen and use a pointer to indicate the important aspects of each view graph.

Students should not plan to write and create view graphs as they talk because the activity can distract the audience and nervousness may cause the presenter to forget all the items or to have difficulty writing exactly what was planned.

The presenter should remember to look at the audience, not just at the screen or the pointer. And most of all, the presenter should try to smile throughout the talk. Smiling forces the presenter to look at the audience and has the effect of calming the presenter's nerves. The presenter should remember that he did the project, wrote the paper, and is now in charge. The presenter should try to relax and enjoy the presentation because everyone wants to hear about the project.

If the presenter makes a mistake while talking, and it is not significant, she should just continue the talk. Otherwise, quietly clear up the mistake. Most audiences are sympathetic and welcoming to students!

Answering Questions

Just as important as the formal presentation of the paper is the question and answer period at the end of the talk or poster presentation. At this point, students' comprehension of their project is under fire. They must be prepared to answer questions about any area of their research. Most often, students receive questions about their methodology, results, and conclusions. They may also be asked about their errors

and mistakes or about topics that are outside the scope of their immediate research project but in the general field.

Students can prepare for the question and answer period by brainstorming a list of questions they may receive and then practicing the Q and A period with classmates. Students need to remember that they are experts on their project.

If students are giving a talk before an audience or during a competition and no one asks questions, prepare the students to step in with some of the following discussion strategies:

- Although there are no questions, perhaps you would like to know why I chose to use this (method, medium, or kind of experiment). . .
- You may want to know why I think these results are (inconclusive, unusual, or excellent). . .
- I was surprised to discover . . .

The most important thing for students to remember when answering questions is to be honest. Let your students know that if they do not know the answer or never thought to look at the problem in that particular manner, they should not be afraid to say, "I do not know." The judge may use a trick question to see whether students actually know what they are talking about. It may be a question that only a Ph.D. or graduate student would understand, or a question without an answer. Although most audiences are welcoming, judges sometimes have to ask tough questions to discriminate among students vying for a scholarship.

Students should not be afraid take a little time when answering a question. They should take a few moments to think about their response so they can avoid repeating part of their formal presentation. If students have already stated the answer in their talk, they should give an answer that doesn't repeat their exact words. To the best extent possible, they should find synonyms for their original words. Sometimes the judge or audience is just looking for a clarification.

While answering questions, students should make sure not to lose their composure. They should not become impatient or intolerant of the person asking questions. Student presenters should give the impression that they are in control. After all, everyone has come to listen to them and to find out the results and conclusions of their experiment.

Ethical and Moral Considerations

Science research does not occur in a vacuum. No matter how new, notable, or important the students' discoveries, other people will have contributed to their research. It is crucial to the integrity of the students' research to acknowledge contributions by other researchers.

In the national competitions, judges and readers look very closely at students' citations and bibliographies. Because the judges and readers are usually professionals in the students' own research area or one closely related, they know or have read much of the available literature in that field. The judges and readers are looking for the necessary citations and references. At poster presentations, judges often ask specific questions about the references, bibliography, and previous research in the field.

One of the major concerns the judges and readers have is plagiarism. In addition to plagiarism, the judges encounter students who may have given a false impression about their results by

- Inflating their claims by overstating their findings
- Ignoring or avoiding the negative aspects of their research
- Padding the bibliography or reference list

Thus, it is important both for the integrity of the research and the students' own integrity to discuss ethical and moral issues in a research class.

Safety Considerations

Safety is an important issue in laboratory research, and every student should receive instruction in how to work safely in a laboratory. Some important points to discuss with students include the following:

- **Work Gloves.** Work gloves cannot prevent hand accidents; only safe and conscientious work practices can do that. But choosing the right work glove for the job can help protect students from unnecessary injury and disability. Make sure that gloves fit well, are comfortable to wear, and are rated to guard against the particular hazards that the students may encounter.

- **Eye Protection.** No matter where a student works, flying particles, dusts, fumes, and vapors are apt to expose the students to potential eye injury. The most common types of protective eyewear include safety glasses, safety goggles, shields, and helmets.

- **Chemicals.** Corrosives, solvents, and other chemical substances are potentially dangerous and must be handled, stored, and disposed of in specific ways. To protect your students, teach them to carefully read container labels, to always add the acids to water and not the other way around, and to use appropriate personal protective equipment. It is also important for students to know not to sniff the chemicals and not to wear contact lenses in the lab.

Although students will also be taught specific safety techniques in each laboratory or research area they use, it is important to occasionally remind students of safety hazards.

6 The Next Steps

Now that you have begun your program, it is important to take steps to not only maintain your program, but to let it grow. Each school and program will develop its own culture and strengths.

At Ward Melville High School, the Science Olympiad Competition became the pivotal event. The students enjoyed their research projects and were very successful with them. The Science Olympiad, with its opportunity for a team competition, pulled the students together and fostered an atmosphere of cooperation. Students would begin to work on the Olympiad at the beginning of the school year. An entire culture sprung up about the competition. Over the years, students began to involve community members as assistant coaches and advisors for various events, such as the model airplane and balsa bridge building competitions. The students devised a yearly competition for the T-shirt design and alumni came home from college to help prepare the students for the Olympiad. Alumni also become assistant coaches and judges at the competition. Some alumni began Science Olympiad teams in their college towns to continue the tradition. Some students from Ward Melville would apply to these colleges where the alumni were coaching college teams and volunteer to take over the teams if they were accepted into the college! Interestingly enough, in every case the student was accepted by the college.

At other high schools, the culture evolved differently. Some schools fostered very close relationships with their research labs. Seniors introduced younger students to their research lab so that the projects they started could be continued or expanded. They invited speakers to come

to the high school to explain the research opportunities available at their laboratories. Some students enrolled in nearby colleges so that they could continue with their research and their relationships. Several students also graduated from colleges out of the local area, but then returned to work for the laboratory or institution that had given them an internship.

In one area of the country, several high schools banded together to form a local science fair. This allowed all students to present their projects before a forum of their peers. The schools looked to the community for judges, prizes, and other support. The community willingly gave of its time and expertise. Several years after the fair was created, a second group of high schools in a nearby county began the same kind of fair. Local businesses became very interested in these fairs and gave internships as prizes to the students. After several years, the businesses found that the internships were beneficial to them as students graduated college and came back to work for the company that had given them the internship.

Throughout this book, I've given examples of what can be done to initiate a research program in your school. I emphasize that you must focus on the activities that work in your school and your community. To keep your program successful, you must continue to maintain the basic activities that you use to initiate the program and slowly add new activities to make it more interesting.

Appendix I: The Competitions

Entering competitions allows students to share the information gained from projects and experiments with other students, teachers, and professional scientists. Before encouraging students to enter a major competition, enter or attend a local competition to begin to learn about the process of competing. Perhaps there is a science or social studies competition within the school. If not, do research in the local area to see what competitions exist in your county or region. If no such competitions exist in your area, determine the statewide competitions available and the requirements to enter. Take your students to any local competitions or academic fairs you can possibly get to as a way of exploring the world you are about to enter.

The following is a list of the major competitions in the United States.

National Competitions

Competition rules and information change frequently. Internet addresses have been included where possible to help you find current information.

The DuPont Challenge/Science Essay Awards Program

Participants: Students in grades 7–12.

Format: Students are required to submit essays from 600 to 1,000 words on a scientific topic and its impact on society. Research is done using

the library or the Internet.

Awards: Educational grants

For information, contact Science Essay Awards Program, c/o General Learning Corp., 60 Revere Drive, Northbrook, IL 60062-1563. Web site: <http://www.math.uni.edu/IMSC/Contests/DuPontEssay.html>

Duracell Scholarship Competition

Participants: Students in grades 7–12. Students may enter individually or in teams of two.

Format: *Round I.* Students design and build a device that runs on Duracell batteries. Students must send in a photograph, wiring diagram, and a two-page description of the device.

Round II. The top 100 finalists (or pairs) are notified and asked to send in their devices for the final judging.

Awards: Scholarships

For information, contact Duracell Scholarship Competition, National Science Teachers Association, 1840 Wilson Blvd., Arlington, VA 22201-3000. Phone: (703) 243-7100. Web site: <http://www.nsta.org/programs/duracell.shtml>

INTEL Science Talent Search

See Science Talent Search Competition for details.

International Bridge Building Contest

Participants: Students in grades 9–12

Format: *Round I.* Regional. Students compete by building bridges of bass or balsa wood given certain specifications and constraints. The specifications change each year. Bridges are tested for efficiency. The most efficient bridges are the winners.

Round II. International. The two top winners from the regional event are eligible to participate in the national competition. The competition is held in various U.S. cities.

Awards: Scholarships and prizes

For information, contact Department of Physics, Illinois Institute of Technology, Chicago, IL 60616. Web site: <http://www.iit.edu/~hsbridge/>

INTEL International Science and Engineering Fair

Participants: Students in grades 9–12 may enter either individually or in teams of up to three students.

Format: *Round I.* Regional. Students submit completed science, engineering, and math independent research papers to regional coordinators. Selected papers are then presented to judges. Two individuals and one team are named finalists from each regional competition and compete in the international event. Project categories include Behavioral and Social Science, Biochemistry, Botany, Chemistry, Computer Science, Earth and Space Sciences, Engineering, Environmental Sciences, Mathematics, Medicine and Health, Microbiology, Physics, and Zoology.

Round II. International. At the ISEF, students set up poster presentations and are interviewed by a panel of judges. The international fair is held annually in different cities throughout the world.

Awards: More than 550 competitive awards are presented to the students.

Sponsor: The ISEF is administered by Science Service and funded by the INTEL Corp.

For information, contact Science Service, 1719 N St., N.W., Washington, DC 20036. Web site: <http://www.sciserv.org>

International Science Olympiads

Participants: Students in grades 9–12

Format: The International Science Olympiads are six highly selective competitions. The competitions are in the fields of mathematics, physics, chemistry, biology, computer science, and astronomy. The format is followed for each field.

Round I. A written test in any one of the given areas. This round is open to all U.S. high school students.

Round II. A select group from Round I is given a second written exam in that same field.

Round III. The top students from Round II are then selected to attend a national camp in their field of study for two weeks during the summer. The top four students from the camp are then chosen to participate in the International Olympiad.

Awards: The top students from Round II receive an expenses-paid.

two-week trip to a study camp. The top four students from the camp are then chosen to participate in the International Olympiad.

Information is available through their Web site: <http://www.olympiads.win.tue.nl/>

JETS—Junior Engineering and Technical Society, Inc.

TEAMS—Tests of Engineering Aptitude, Mathematics, and Science

Participants: Students in grades 9–12. Schools may enter teams of four to eight students on both varsity teams and junior varsity teams.

Format: The TEAMS exam is given in two parts. The first part consists of a series of objective (multiple choice) questions related to various engineering situations. The second part requires students to describe and defend their solutions to open-ended, subjective questions related to some of the problems they worked through on the first part.

Awards: Various

National Engineering Design Challenge

Participants: Students in grades 9–12

Format: This competition requires teams of students to design and build a working model of a solution to a societal problem that is given to them. Students are given a set of specifications and constraints. The actual problem changes each year. An unlimited number of students may work on the project; only five students may present the finished project at the competition.

Awards: Scholarships and prizes

For information, contact JETS, 1420 King Street #405, Alexandria, VA 22314. Phone: (703) 548-5387. Web site: <http://www.jets.org/>

Junior Science and Humanities Symposium (JSHS)

Participants: Students in grades 9–12

Format: *Round I.* Regional. Students submit completed independent research papers to regional coordinators. Selected papers are then presented to judges. The 45 regional symposiums are conducted throughout the United States, Puerto Rico, and various U.S. Army bases around the world.

Round II. National. First place winners from each regional compe-

tition compete in the National Junior Science and Humanities Symposium. The alternates also attend the presentations.

Awards: *Round I.* One finalist and four alternates are selected to attend the National Junior Science and Humanities Symposium. Only finalists present and compete at the national competition.

Round II. Scholarships and an all-expenses-paid trip to the London International Science Youth Fortnight.

For information, contact Academy of Applied Science, 98 Washington St., Concord, NH 03301. Phone: (603) 228-4520. Web site: <http://www.jshs.org/national.htm>

NASA Student Involvement Program

Participants: Students in grades 3–12

Format: The program provides opportunities for students and teachers to expand their knowledge of science, mathematics, engineering, technology, and geography through competitions that include actual or simulated problems or challenges of real-world science, mathematics, engineering, technology, and geography activities.

Awards: Certificates, plaques, and all-expenses-paid trips

For information, contact NSIP, c/o TERC, 2067 Massachusetts Ave., Cambridge, MA 02140. Web site: <http://www.nsip.net>

National Council of Teachers of English (NCTE)

Participants: Students in grade 11

Format: Each high school selects its own nominee or nominees; one or more juniors agreed upon by the English department. Students must submit two written compositions on selected topics which change from year to year.

Awards: Achievement awards, certificates

For information, contact Achievement Awards in Writing, National Council of Teachers of English, 1111 W. Kenyon Road, Urbana, IL 61801-1096. Phone: (217) 328-3870. Web site: <http://www.ncte.org>

The Scholastic Art and Writing Awards

Participants: Students in grades 7–12

Format: The Scholastic Art and Writing Awards program was estab-

lished to encourage and recognize student achievement in the creative arts. Individual awards are offered in 16 categories of the visual arts and 9 categories of writing. Students enter portfolios of written and artistic work.

Awards: More than 1,000 awards in cash, scholarships, certificates, and exhibition, reading, or publishing are given each year.

For information, contact Scholastic, 555 Broadway, New York, NY 10012. Web site: <http://www.scholastic.com/artandwriting/>

Science Olympiad

Participants: Students in grades 9–12

Format: *Round I.* Regional. The Science Olympiad is a team competition. A team is composed of 15 students who participate in more than 20 different events. The events are diversified and chosen from all areas of science including biology, chemistry, earth science, and physics, as well as mathematics and computer programming. The events change every year.

Round II. State. Winners of the regional events are eligible to compete in the state event.

Round III. National. Winners of the state event are eligible to compete in the national competition.

Awards: Individual gold, silver, and bronze medals are awarded for each event at each level. Team trophies are also awarded. Scholarships are awarded at the national competition.

For information, contact Science Olympiad, 5955 Little Pine Road, Rochester, MI 48064. Web site: <http://www.macomb.k12.mi.us/science/olympiad.htm>

INTEL Science Talent Search

Participants: Students in their graduating year of high school

Format: *Round I.* The Science Talent Search is a competition to discover high school seniors with the potential to become the research scientists and engineers of the future. Students submit a paper describing an original science research project and the results. The paper should be a minimum of 5 pages and a maximum of 20 pages.

Students also complete an entry form containing objective questions

about the student, the research project, and the student's promise as a scientist. Students complete several essays on topics such as "scientific attitude" and "scientific curiosity." Students submit copies of their transcripts, SAT scores, and letters of recommendation from teachers and mentors.

Round II. Interviews with the finalists.

Awards: Semifinalists receive certificates and national recognition. Finalists receive an all-expenses-paid trip to Washington, DC, and scholarships.

For information, contact Science Service, 1719 N St., N.W., Washington, DC 20036. Web site: <http://www.sciserv.org/sts>

Siemens Westinghouse Science and Technology Competition

Participants: High school students as individuals or in teams of up to three students.

Format: *Round I.* Regional Competition

Round II. National Competition for Regional Finalists. Interviews with the Finalists.

Awards: About 500,000 in total awards each year.

Contact Siemens Foundation, 1301 Avenue of the Americas, New York, NY 10019. Web site: <http://www.siemens-foundation.org>

State Science Talent Searches

Participants: Students in their last year of high school

Format: The state science talent search bases its competition on the research papers of graduating high school students who are also entering the Science Talent Search Competition. The searches are held concurrently with the National Science Talent Search by special arrangement with Science Service.

Awards: Certificates and cash awards

For information, contact Science Service, 1719 N St., N.W., Washington, DC 20036. Web site: <http://www.sciserv.org>

ThinkQuest

Participants: Students in grades 7–12, participating in teams of two or three students

Format: Students produce sets of Web pages as teaching and learning tools for use by teachers and students around the world. Projects may be entered in five awards categories: Arts and Literature, Interdisciplinary, Science and Mathematics, Social Sciences, and Sports and Health.

Awards: More than a million dollars in scholarships and awards. For information, see <http://www.advanced.org>

Contests and Web addresses frequently change; to find information on competitions, type terms such as “academic contests” or “math contests” or “English competitions” into various Internet search engines.

Appendix II: Sample Project Titles

In the last 15 years, my students have completed more than 1,000 projects in the following categories. I've listed some of the project titles to give you a sense of the range, scope, and types of possible projects.

Behavioral and Social Sciences

The Behavioral and Social Sciences include psychology, sociology, anthropology, archaeology, ethnology, linguistics, animal behavior (learned or instinctive), learning, perception, urban problems, reading problems, public opinion surveys, and educational testing. Here are sample project titles:

- Anatomical and Cognitive Features of Preattentive Visual Processing Through Psychophysical Experimentation
- Testing the Effect of Suggestions on Subliminal Perceptions
- A Study for the Preference for Peer Counseling Among Children of Divorce
- Relative State Power in the United States Senate
- Problems Encountered in the Decision Making Process
- Myers-Briggs Psychological Types and Scholastic Achievement
- Odin as an Indefinite Article in Russian and the Universal Evolution of the Numeral 'One' into an Indefinite Article
- A Survey of Geographical Knowledge
- Gender Differences in Everyday Knowledge
- Chess Ability: A Study into Linguistic Ability Versus Intelligence

Quota

- A Study of the Possible Relationships Between Grade Point Average, Sex, and Logic Testing Technique and Ability
- The Effects of Media on Political Campaigns
- The Comparison of the Proportionality of Left-Handed People in Honors and Accelerated Classes as Compared to That in Regular Classes

Biochemistry

Biochemistry includes molecular biology, molecular genetics, enzymes, photosynthesis, blood chemistry, food chemistry, and hormones. Here are sample project titles:

- Movement of Neutrophils Stimulated by Chemoattractant
- The Effects of Ethylene Glycol on Conductivity and Diffusion in the Septate Median Giant Axon of the Earthworm *Lumbricus Terrestris*
- Analysis of Assumed Correlation between the Concentration of Ascorbic Acid in Fruit Juices and Human Taste Response
- Weak Inhibition of Activated Human Coagulation Factor X by Soybean Trypsin Inhibitor (Kunitz)
- Double NOR (dNOR) as a Risk Factor for Trisomic Offspring
- Comparing the Effects of Brain Extract and Ascorbic Acid on Acetylcholine Receptor in Chick Myotubes

Botany

Botany includes agriculture, agronomy, horticulture, forestry, plant biorhythms, paleontology, plant anatomy, plant taxonomy, plant physiology, plant genetics, hydroponics, algology, and mycology. Successful project titles from my students include the following:

- Tomato Spotted Wilt Virus
- The Effects of the Algae *Codium Fragile* Used as a Fertilizer on the Growth of Plants: A Two Year Study
- The Effect of Phosphorus and Magnesium on Radish Plant
- The Effects of Acid on Plant Growth

Chemistry

Chemistry includes physical chemistry, organic chemistry (other

than biochemistry), inorganic chemistry, materials, plastics, fuels, pesticides, metallurgy, and soil chemistry. Project titles include the following:

- Organic Chemistry: Formal Replacement of Oxygen by C_2H_4 Groups to Form Organic Carbonate
- The Use of Synthetic Protein as a Substitute for Phytoplankton with Rotifers
- A Transient Electric Birefringence Study of DNA Fragments in Agarose Gels
- Boundary Layer in Viscous Fluid Flow
- The Liberation of Hydrogen from Water
- Volatile Chemical Utilization for Domestic Energy Cooling
- Ionization in Water's Surface
- Theory Analysis of Chloride Induced Stress Corrosion Cracking in Austenitic Stainless Steels

Computer Science

Computer Science includes new developments in software or hardware, information systems, computer systems organization, computer methodologies, and data (including structures, encryption, coding, and information theory). Projects using existing computers or applying computer procedures to scientific problems should be entered in the area of basic science to which the application is made, not in the Computer Science category. Here are examples of project titles my students have presented:

- Computer Methodologies: Statistical Analysis of Randomness of Random Number Generators
- Interactive Human Networking via Interprocess Communication (the CHAT System)
- TOOLS—A Natural Language Database System
- Computer Simulated Behavior of a Network of Model Neurons
- Development of a Meta-Language Computer Programming Environment
- General Purpose Anti-Virus Program in C
- Distributed Parallel Processing

Earth and Space Science

Earth and Space Science includes geology, geophysics, physical oceanography, meteorology, atmospheric physics, seismology, petroleum, geography, speleology, mineralogy, topography, optical astronomy, radio astronomy, and astrophysics. Titles of projects that fall into this category include the following:

- Control of Growth Patterns: The Response of Bean Roots to Centrifugal Force and Gravity
- Fundamental Design Concepts of a Low-Tech, Cost-Effective Space Transportation System
- On the Trochoidal Waves of Gerstner and Rankine

Engineering

Engineering includes civil, mechanical, aeronautical, chemical, electrical, photographic, sound, automotive, marine, heating and refrigerating, transportation, and environmental engineering; also power transmission and generation, electronics, communications, architecture, bioengineering, and lasers. Here are the titles of some successful projects:

- Mechanical and Electrical Feedback: The Eyes, Ears and Senses of Robots
- Demonstrations of Single-Beam Holography and the Various Conditions Causing Vibration
- The Carnot-Diesel Cycle: An Ideal for Internal-Combustion Engines?
- Enhancement of Building Heating System: A Measure of National Energy Conservation
 - Light Feet—Electro-Magnetic Sneaker
 - Heat Convection Mechanism of Envelope Houses
 - Using a Vertically Rotating Propeller to Increase the Efficiency of the Traditional Windmill
 - Efficient Methods of Conserving Energy Through the Insulation of Basements
 - Pressure Activated Walkway Lights Using Relay Switches

- The Reallocation of Waste Heat in Water Disposal Systems
- Finding the Most Efficient Blade Angles for a Dutch Windmill
- A Comparison of Various Modern Wind Turbine Variables with Their Possible Effectiveness on Primitive Windmills

Environmental Science

Environmental Science includes pollution (air, water, land), pollution sources and their control, waste disposal, impact studies, environmental alteration (such as heat, light, irrigation, and erosion), and ecology. Here are sample project titles:

- The Practical Use of Earth Sheltered Housing in Energy Conservation
- Fire's Role in the Natural Ecosystem with Specific Investigation and Recommendation for Land Management Policies in Suffolk County, NY
- High Efficiency Hydro-Vaporizing Cooling System
- Reducing Heat Loss in Solar Homes by Applying Synthetic Materials
- Exothermic Reaction as an Alternative Energy Source for Heating System
- The Compost Water Heater
- Methane Energy from Bacterial Decay of Garbage
- Water Purification Through an Enhanced Evaporation-Condensation Process

Mathematics

Mathematics includes calculus, geometry, abstract algebra, number theory, statistics, complex analysis, probability, topology, logic, operations research, and other topics in pure and applied mathematics. Among successful projects are those with the following titles:

- Plotting Catenaries and Other Hanging Chain Curves Using Vector Constructions
- Finite Polynomial Fields in Binary
- Fourier Polynomials and Polyhedrons

- Conjectures Towards a Polynomial Expansion Theorem
- Application of the Laplace Transform to the Solutions of Certain Initial Value Problems of Differential Equations
- Cubic Spline Interpolation
- Mathematical Design of an Efficient Collector of Wave Energy
- Hysteresis and the Structure of Fractal Basin Boundaries in the Hénon System
- Factoring $(X^n - 1)$
- Toward a General Definition of Chaos
- On Constructing Polygons on Orthogonal Integral Lattices
- Comparing Cardinalities of Infinite Sets
- A Methodology for Projecting the Population Center of the United States: April 1, 1990

Medicine and Health

Medicine and Health includes medicine, dentistry, pharmacology, veterinary medicine, pathology, ophthalmology, nutrition, sanitation, pediatrics, dermatology, allergies, speech and hearing, and optometry. Here are examples of successful project titles:

- Determination of the Mechanism of Anesthetic Action Through the Electro-Neurophysiological Analysis of the Temperature Dependence of Various Kinetic Properties in BC3H-1 Murine Intracranial Tumors
- Lyme Borreliosis in Cattle: Characterization of the Immune Response and Evaluation of Serological Testing
- The Contribution of the Neutralization Antigenic Site I to the Immunogenicity of the Poliovirus in Human Beings
- Characterization of the Generation and Inhibition of Factor A in the Human Blood Coagulation System

Microbiology

Microbiology includes bacteriology, virology, protozoology, fungal and bacterial genetics, and yeast. Successful projects have had following titles:

- Development of a Method Using Household Reagents to Deproteinize DNA Extracted from *Artemia salina*
- Elisa Analysis of Some Complement Proteins

Physics

Physics includes solid state, particle, nuclear, atomic, and plasma physics, as well as superconductivity, fluid and gas dynamics, thermodynamics, semiconductors, magnetism, quantum mechanics, and biophysics. Examples of project titles used by my students follow:

- Diode Laser Narrowing Using a Diffraction Grating
- The Effects of Colorants and Temperature on a White Clay Body
- An Experiment to Evaluate the Validity of the Yttrium Barium Copper Oxide Based Superconductor
- Creating Resonance in Rubidium-85 using an AlGaAs-GaAs Diode Laser
- Piezo-Electric Nighttime Illumination System
- Fiber Optics: Increasing Lighting Efficiency

Zoology

Zoology includes animal genetics, ornithology, ichthyology, herpetology, entomology, animal ecology, anatomy, paleontology, cellular physiology, animal biorhythms, animal husbandry, cytology, histology, animal physiology, neurophysiology, and invertebrate biology. Examples of successful project titles include the following:

- Exogenous ATP Is Not Required for Pronuclear Formation in Vitro
- A Study of the Correlation Between Left and Right Clawed Fiddler Crabs and Their Body Dimensions
- Observing Two Competing, Mating Males of the Firefly, *Photinus Macdermotti*
- Effects of Various pH Levels on the Growth Patterns of *Artemia Salina*
- Discovering Female Response to Altered Male Flash Patterns in the *Photinus* Firefly Mating System

Appendix III: Opportunities for Students

Working on an independent research program during the summer at a camp or at a university can be quite exciting. As students work with professional scientists, they will discover that they are treated as professionals, that their opinions and their work will become important, and that the work they complete will become an intrinsic part of the ongoing project.

Summer Training Programs

There are many programs available to high school students interested in working on independent research projects. These programs give training to student participants and offer one of the easiest ways to get started in independent research. Summer programs can be in either day or residential camps, and positions in the camps are often filled on a competitive basis.

There are three major program arrangements: (1) students are given course work on various topics to gain background information for future independent research projects, (2) students are given course work and provided with a mentor who involves the students in independent research during part of the day, or (3) students are immediately set up in a laboratory and work throughout the summer on an independent research project.

Science training programs usually assign each student to a mentor. The mentor helps the student develop a set of simple original experiments for an independent research project. In most cases, students are expected to pay for room, board, travel, and tuition. Liberal scholarship

money, however, is available for many students.

Science Service publishes a list of research programs. For information write to Science Service, 1719 N St., N.W., Washington, DC 20036. Web site: <http://www.sciserv.org>

College Programs

During the summer, many colleges allow high school students to participate in college-level courses. These courses not only give students a taste of the scope and level of a college course, but also can be directly related to a research project.

After signing up for a course, students need to speak to the professor or department chair about working on an independent research project. Many times the professors allow students to observe the projects and experiments in progress and to participate in some research work in the lab. Colleges also allow students to use the library facilities for their research.

Science Service publishes a list of training programs for students and teachers in science, math, and engineering. For information, write to Science Service, 1719 N St., N.W., Washington, DC 20036. Web site: <http://www.sciserv.org>

Center for Talented Youth (CTY)

Although courses offered through the Center for Talented Youth of The Johns Hopkins University are not research-oriented, they give students an excellent background in many research areas. The CTY courses may give students ideas that could be used for research projects. Qualified students with a very high score on the SAT (taken before the 13th birthday) will be able to attend courses for talented and gifted students at sites throughout the United States. The score required for entry in The Johns Hopkins CTY program varies with age. For specific information about the required score at specific sites, write to Institute for the Academic Advancement of Youth, The Johns Hopkins University, 3400 N. Charles St., Baltimore, MD 21218. Web site: <http://www.jhu.edu/~gifted/>

About the Author

Melanie Jacobs Krieger is Director of Research in the Plainview-Old Bethpage Central School District in Plainview, New York. She coordinates all aspects of the curriculum and process for students K-12 to enter research and academic competitions. Krieger's work includes setting up an independent research program for the high school and Independent Research Clubs for the middle schools. She coordinates staff development for teachers K-12 to enter the various national competitions, including the Intel (Westinghouse) Science Talent Search, the Science Olympiads, and ThinkQuest.

In 1986, Krieger wrote the curriculum for the West Prep Program at Ward Melville High School in Setauket, NY. Students studied statistics and research methods and they learned how to write mathematical and scientific papers and how to present their papers. As part of the curriculum, students entered a plethora of competitions, such as the L I Science Congress, International Science and Engineering Fair (ISEF), Science Olympiad, NSTA's Space Science Involvement Program, and the Westinghouse Science Talent Search Competition. In 12 years, there have been 83 Westinghouse Semifinalists and 16 Finalists in the West Prep program.

In both 1997 and 1998, Ward Melville High School had the most Westinghouse Finalists of any high school, public, private, or magnet, in the United States.

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About ASCD

Founded in 1943, the Association for Supervision and Curriculum Development is a non-partisan, nonprofit education association, with international headquarters in Alexandria, Virginia. ASCD's mission statement: *ASCD, a diverse, international community of educators, forging covenants in teaching and learning for the success of all learners.*

Membership in ASCD includes a subscription to the award-winning journal *Educational Leadership*, two newsletters, *Education Update* and *Curriculum Update*, and other products and services. ASCD sponsors affiliate organizations in many states and international locations; participates in collaborations and networks; holds conferences, institutes, and training programs; produces publications in a variety of media; sponsors recognition and awards programs; and provides research information on education issues.

ASCD provides many services to educators prekindergarten through grade 12 as well as to others in the education community, including parents, school board members, administrators, and university professors and students. For further information, contact ASCD via telephone: 1-800-933-2723 or 703-578-9600; fax: 703-575-5400; or e-mail: member@ascd.org. Or write to ASCD, Information Services, 1703 N. Beauregard St., Alexandria, VA 22311-1714 USA. You can find ASCD on the World Wide Web at <http://www.ascd.org>.

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How to

CREATE AN INDEPENDENT RESEARCH PROGRAM

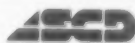
Only a few hundred schools across the United States have research programs. Although some of the schools with programs are magnet schools or highly advantaged schools, many ordinary schools have successful programs. Every school is capable of at least a modest program for those students who want to work on independent research projects.

This practical book provides a school district with a comprehensive guide on how to establish an independent research program. Use this book as your step-by-step guide to creating your own program and preparing your students to enter the national independent research competitions. Krieger takes you from selling the idea of the program to educators, students, and the community through critical curriculum and methodology for the teacher, to finally entering national research competitions and continuing your program.

Although the curriculum described in this book is based on the objectives of various national competitions, the course is not competitive and the students are not in a competitive environment. Instead, the competition rules are used to create a working atmosphere that resembles the professional world.

Melanie Jacobs Krieger has been working with independent research programs since 1986. She is Director of Research in the Plainview-Old Bethpage Central School District in Plainview, NY.

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